Space Weather Technical Forecast

Issued on Monday, 20 February 2023 at 12:53 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Awaited 17 February X2.2-related CME shock arrived at Earth 20/1045UTC, Chance of G1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours, with frequent mid-level C-class flares recorded at GOES16. The largest of these flares was a C7.1 observed at 20/0702UTC from near the leading spot of AR3226 in the northwestern quadrant, with the spot group itself otherwise showing visual fading in its trailing portion, finishing the reporting period as a Cho/Beta.

The above region was one of up to eight present on the disc in the period, with up to two developing regions yet to attain numbers, and with AR3225 becoming indistinct on the southwestern solar horizon. Of the current sunspot groups, perhaps the most noteworthy in terms of trends and appearance have been the proliferation of trailing spots in AR3231 in the northwest, which became a Dao/Beta. The trend in AR3226 was the reverse, with significant fading of its trailers, while AR3229 remains the largest and nominally most potent spot group, with Eki/Beta-Gamma-Delta classification and some mobility in its central spots, including its tenuous delta.

Potential Coronal Mass Ejection (CME) candidates seen on coronagraph imagery for the period included a prominence eruption from the southwest during the UTC afternoon of Sunday 19 February, erupting from near AR3217. The track of this feature appears to closely follow an earlier CME from the southwest prior to the start of this 24-hour period (this earlier event being an analysed miss). The prominence eruption has been analysed as carrying a small chance of delivering a glancing interaction late on day 3 or early day 4 (Wednesday 22 or Thursday 23 February). Also observed in coronagraph imagery was late afternoon and early UTC evening northeastern limb series of minor flares and dimmings - with a possible spot-containing plage now becoming visible in a similar location. This event has yet to be analysed, however any Earth-directed component is considered unlikely.

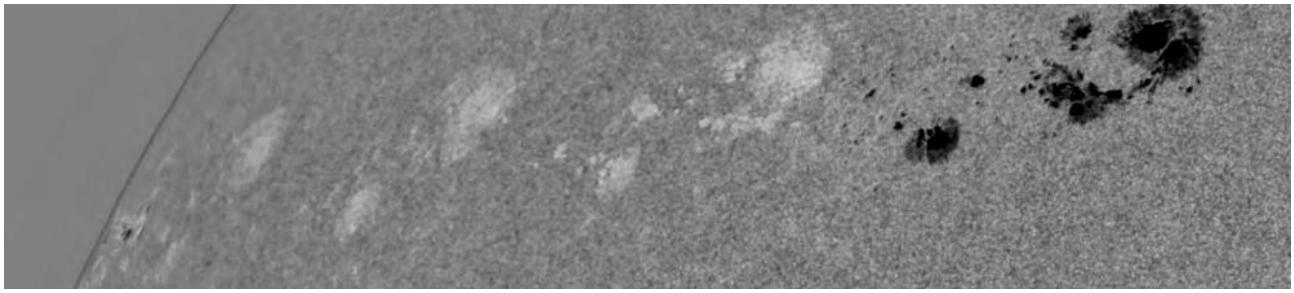

Figure 0: Helioviewer.org-generated HMIIF evolution of the footprint of AR3229, the sunspot group responsible for the X2.2 flare on 17 February in 24-hour HMIIF difference imagery steps (17, 18, 19/1200UTC steps in white; 20/1200UTC in black). Note the slight areal growth in the intervening time since the X2.2.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR and ACE at L1, were

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mostly suggestive of a slow regime, but giving way to a probable arrival of the awaited shock from the 17 February X2.2-associated CME as of 20/0952UTC. This reached Earth-based magnetometers at 20/1045UTC, with BGS Hartland seeing a modest 15nT deflection in the H-component at this time.

As such, the solar wind speed mostly varied with a rough envelope of 350+/-25km/s, but showed a late increase to 425km/s. The solar wind density was also mostly in its normal Background range in single figures ppcc, but increasing to the high teens after the CME shock arrival. This was mirrored in a notable and ongoing increase in low energy protons at the ACE EPAM LEMS instrument. This tendency has been roughly mirrored at STEREO A in the PLASTIC instrument, with this satellite more in-line for effects given the expected fuller hit. Back at L1, the IMF showed a stable trend with a peak of 7nT, giving way to a new higher magnitude and a 16nT peak after 20/0952UTC. The north-south component varied between +/-5nT for much of the period, with a greater amplitude seen after the CME shock passed: -3/+10nT. The phi angle was mainly positive (away from the Sun) but with a few brief forays into negative.

The net result of the above solar wind measures was for Quiet geomagnetic activity, with a provisional peak Kp of '2+' seen in the 12-15UTC interval.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16 remained at Background levels.

High energy electron flux (greater than 2MeV) at GOES16 was at largely Normal Background levels. The associated 24-hour electron fluence has been well below the Active (1e8 integrated pfu) threshold, reaching 7.47e6 integrated pfu at 20/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Mainly Low activity is Expected. Isolated M-flares are Likely, with a Slight Chance of rising again to High with further X-flares - the main risk being from AR3229 in the northeast.

Solar Wind / Geomagnetic Activity: In terms of CMEs, Earth is currently transiting a sector of space being affected by at least the shock from the 17 February CME, with a Chance of G1 for the remainder of the current UTC day. These winds should ease through day 2 (Tuesday 21 February). There is a very low chance of a further CME glance (from 19 February) later day 3 or day 4 (Wednesday 22 or Thursday 23 February), but this is currently not expected.

In terms of coronal holes, a slight enhancement may arise from the CH77 fast wind later day 2 or day 3 (Tuesday into Wednesday 22 February).

All considered, there is a Chance of occasional Minor Geomagnetic Storm G1 intervals for the remainder of the current UTC day, falling with time to a Slight Chance given the CH77 fast wind, and then perhaps a very minor glance from the 19 February CME in turn.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is most likely to remain at background levels, but with a slight chance of rising towards the S1 level, perhaps exceeding it if any larger flares occur.

High energy (greater than 2 MeV) electron flux may increase later in the forecast period in response to the fast wind enhancement, however this is low confidence. The associated 24-hour fluence is expected to remain below the Active threshold (1e8 integrated pfu).

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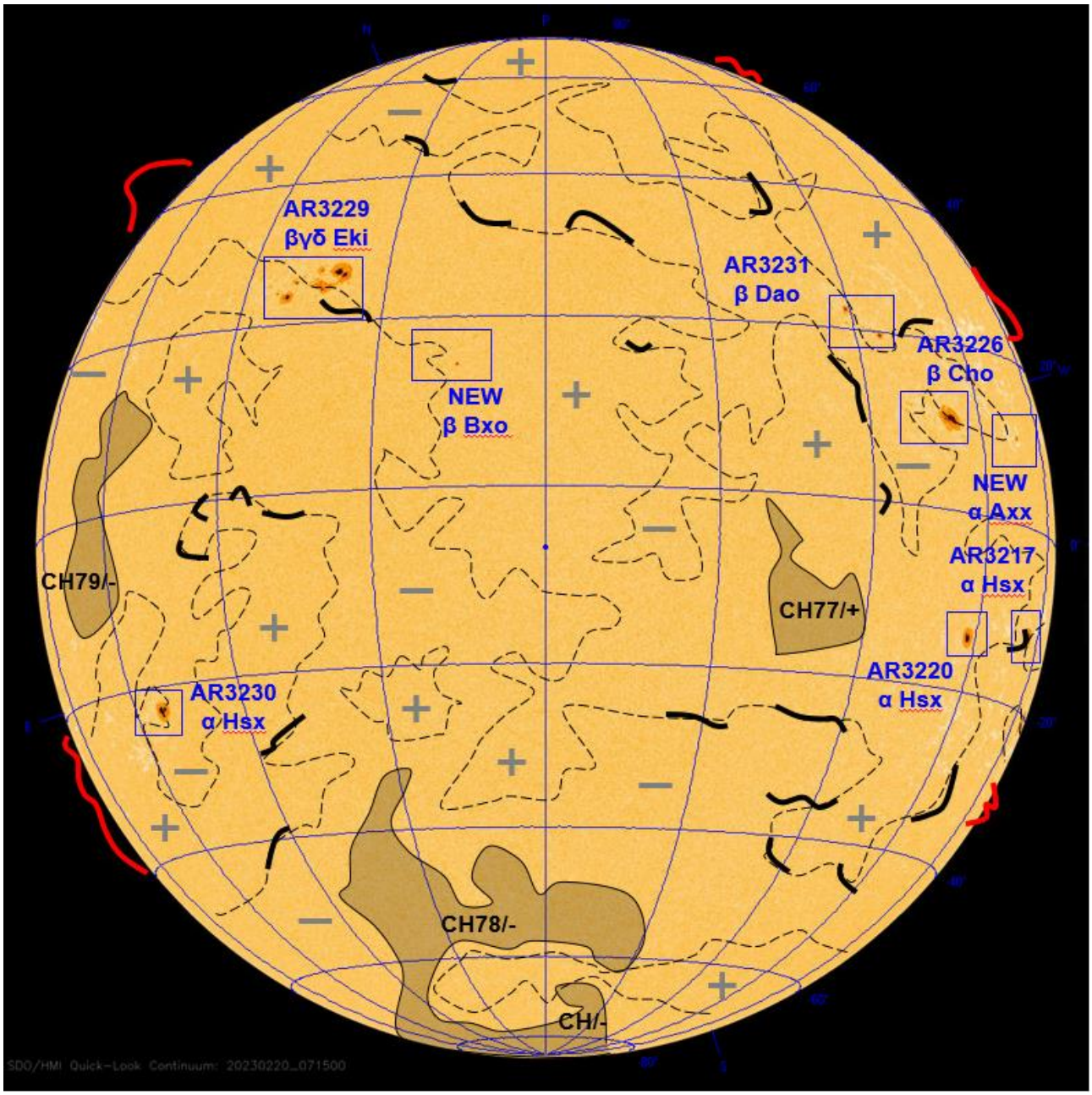
Figure 1. Solar Analysis Valid 20/0715UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A fast CME was observed on 17th with the X2.2 flare from AR3229. This is thought to be the event now seen passing L1 as of 20/0952UTC, reaching Earth-based magnetometers at 20/1045UTC with a 15nT deflection seen in the H-component at Hartland. This event is therefore quite modest at present, but the risk of G1 is preserved should the Bz line up unfavourably for a protracted period. The chances of G2 and G3 are now discounted.

Regarding other transients in the forecast, there is also a CME from a prominence eruption on 19 February, which is expected to most probably miss to the south and west (ahead of Earth), but may give a glancing interaction late on day 3 or early day 4 (Wednesday 22 into Thursday 23 February).

The unperturbed solar wind forecast (i.e. coronal holes) is otherwise for a further enhancement from CH77/+ late day 2 or 3 Tuesday 21 into Wednesday 22 February). This is a persistent feature, although appears a little more ragged on imagery on this occasion. Furthermore, any enhancement is likely to be fairly muted due to its positive polarity and our approach to the (northern hemisphere) vernal equinox.

All considered, geomagnetic activity carries a Chance of reaching G1 within the current UTC day, falling away into Tuesday 21 February. CH77's fast wind should then take up the mantle later in that UTC day, followed by a residual Slight Chance of yet further G1 intervals should the 19 February CME affect Earth after midweek.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	40	20	10	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
19/2320	Partial	Prominence near AR3217	SW limb	662km/s	Probable miss	Some Enlil ensemble members suggest glance late 22 into 23 February.

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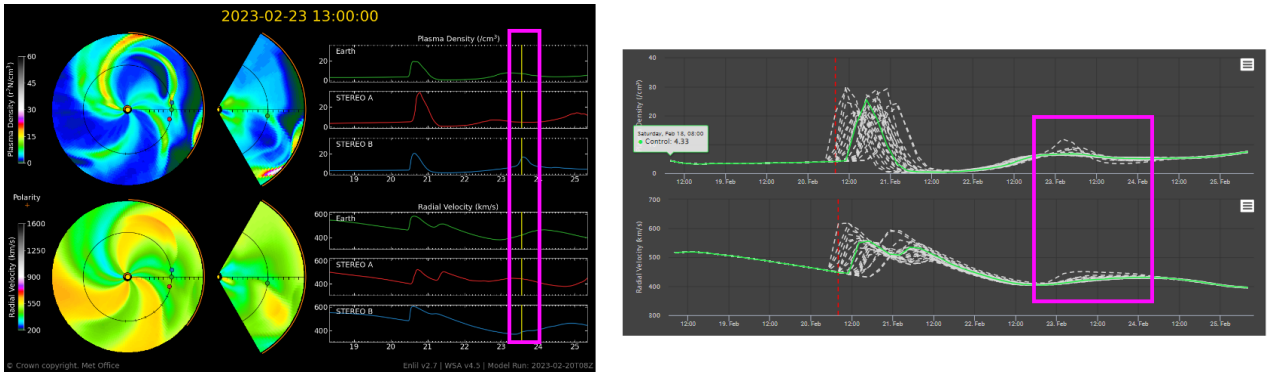
Figure 2: Various measures of the arrival of the 17 February CME at L1 20/0952UTC (DSCOVR speed, density and IMF, left); also ACE EPAM LEMS (upper right); and ground-based instruments at 20/1045UTC (BGS magnetometers' H-component centre and dB/dt lower right).

L1 Solar Wind (speed)
ACE EPAM (LEMS proton flux)
L1 Solar Wind (density)
BGS Magnetometer Obs (H)
L1 Magnetometer (all)
BGS Magnetometer dB/dt (north/south)

Figure 3: 20/0800UTC MOSWOC Enlil run and ensemble, showing a very slight reaction in a few members after midweek UTC to the 19 February CME, with the control and deterministic members both showing misses – this being the favoured forecast.



Radio Blackouts - X-Ray Flares:

Mainly Low activity is Expected. Isolated M-flares are Likely, with a Slight Chance of rising again to High with further X-flares - the main risk being from AR3229 in the northeast.

The main focus of potential activity remains AR3229 in the northeastern quadrant. Changes in this group in recent hours have been slow, with a gradual eastward migration of its intermediate penumbral (possible delta) spots relative to the bulk of the group, with its overall area largely unchanged. This presents as an Eki/Beta-Gamma-Delta at present, which carries significant risks of flares based on the historical record, although the slowing growth trend, its evident maturity, and the fact that its magnetic looping is perhaps now a relatively straightforward arc between the leading and trailing groups on AIA171 - all serve to perhaps tentatively imply a gradually decreasing trend of Friday's events being repeated (X2.2-class flare).

The weight of sunspot groups is otherwise firmly in the western solar hemisphere, with up to five of the current (up to) eight sunspot groups departing the disc in the four-day period. In terms of

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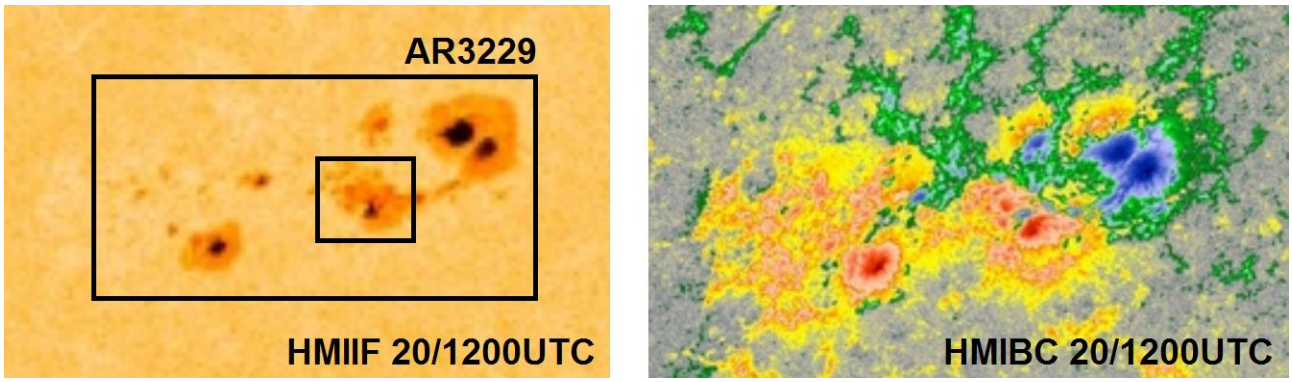
arrivals, the northeastern limb may now be revealing yet another group that potentially generated a CME in the past 24 hours - this seen heading northeast on coronagraph imagery (to no presumed effect at Earth, pending analysis). This and perhaps another two returning regions in the southern solar hemisphere may slow any decline in the front side probabilities of significant flares, although the forecast trend is nevertheless downwards with time.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	No	50	50	40	30
Very Active	**R3 to R5 X Class**	No	15	15	15	10

Figure 4: Appearance of AR3229 at the end of the 24-hour period. Note the (very) tenuous Mt Wilson Delta spot in the mobile central penumbral spot. Despite a recent lack of activity the group remains one to watch.



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Solar Radiation Storms - (High Energy Protons):

High energy (greater than 10MeV) proton flux, as observed by GOES16, is currently at Background levels.

A proton response was not observed from the X2.2 flare on 17 February, however there remains a Slight Chance of further strong flares from this region. There are also a couple of spots in the western hemisphere that have the potential for M-class level flaring, which is a more favoured location for Earth-connecting proton events should they occur. This gives an ongoing Slight Chance of proton count rates breaching the S1 Minor Radiation Storm threshold.

Radiation Storms	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ S1**	No	10	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed at GOES16 is currently at Normal Background levels.

Any more persistent increase in flux is now likely to be suppressed by geomagnetic activity arising from the 17 February CME incipient at Earth. Some recovery towards Moderate levels is then likely after the onset of the CH77 HSS, later day 3 or during day 4 (Wednesday 22 or Thursday 23 February), with a peak Slight Chance this may approach High flux levels by the end of the period.

The associated 24-hour fluence is expected to remain below the Active threshold, with only a Slight Chance of rising above later in the period. REFM maintains below-Active fluence, and this is likely to be a reasonable guide through the period, although the presence of transients (including the current event) serves to lower confidence in its predictions.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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